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AGRICULTURAL EXPERIMENT STATION

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COLLEGE OF AGRICULTURE AND MECHANIC ARTS

WEST RALEIGH

A SERIOUS LETTUCE DISEASE

F. L. Stevens

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SUMMARY.

Lettuce Sclerotiniose, also known as "drop," "damp off," "wilt," etc., is the most destructive lettuce disease in North Carolina (page 8).

It is caused by a fungus (page 12), and is carried from season to season by small black bodies—Sclerotia—which thus serve as the "seeds" of disease (page 13).

Theoretically, if the formation of sclerotia can be prevented, an infected bed can be returned to health.

A practical test has shown how a badly diseased bed has been restored to health (page 16).

Directions for treatment of sick beds are given (page 17).

A SERIOUS LETTUCE DISEASE.

(*Lettuce Sclerotiniose.*)

By F. L. Stevens.[1]

Only a few years ago lettuce was regarded merely as a garden-grown plant for home consumption. It is now, however, an important article of commerce.

Fig. 1.—A lettuce plant suffering from sclerotiniose.

During the last decade there has been a large increase in the shipment from the South to metropolitan markets, particularly from North Carolina and South Carolina where lettuce is grown under cloth, and from Florida where it is grown largely in the open.

Wilmington was the pioneer lettuce-growing community of North Carolina, and the first lettuce raised under cloth for shipment in this State seems to have been grown by D. W. Trask, of Wilmington, about 1892. Three years before other commercial lettuce was produced in Wilmington, Mr. Trask, who raised lettuce in a small way for the

[1] J. G. Hall, former assistant, and G. W. Wilson, present assistant, aided in field work and in preparation of illustrations.

home market, had more than could be sold there and was forced to ship it. This lettuce sold at from $6 to $10 a barrel, and the area under

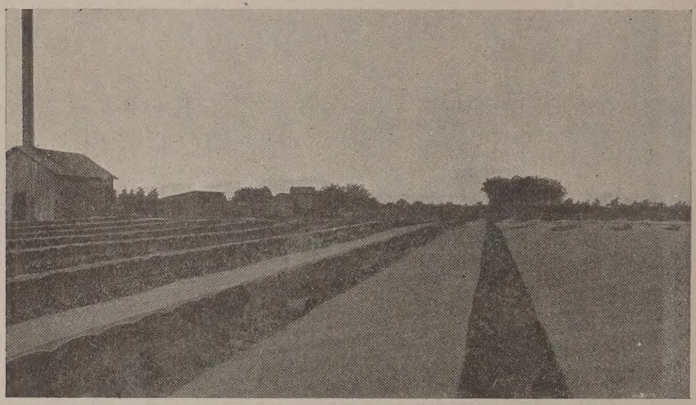


FIG. 2.—Lettuce growing under canvas and with irrigation at New Bern.

cloth was increased the next year to more than an acre. After the third year others began raising this profitable crop, and the area gradually increased until it aggregated between 75 and 100 acres under cloth.

Around New Bern lettuce was first grown for market in 1894.

At Fayetteville, commercial lettuce culture was apparently begun about 1895.

Considerable lettuce is also grown at Wilmington, Maxton, Willard, Raleigh, Faison, Wade, Tarboro, Chadbourn, Warsaw, Mt. Olive, and probably at other places in North Carolina.

Characteristic Symptoms of the Disease.

This disease may readily be distinguished from any other lettuce disease when the specific symptoms are once known.

Of these symptoms the one which first catches the eye of the lettuce grower is the rotting down of his plants in whole or in part. When first observed, a single leaf may be drooping, or wilting; a day or so later the whole plant is involved, the outer leaves dropping flat on the ground, the central head alone remaining standing. At this stage the plant appears as though scalded by an application of hot water. The head also soon succumbs to the rot and topples over. The first conspicuous symptom is this rotting and "dropping" of the whole plant.

Close examination of such rotting plants, especially in the later stages of the disease, reveals the presence of a delicate weft of cotton-like threads on the under side of the affected leaves, especially in the more moist regions, as at the base of the leaves near the stem. This

FIG. 3.—A diseased plant. Note wilt of the outer leaves.

character is limited to sclerotinoise, and is a sure indication of this disease.

In the last stages of the disease, a week or two after the final dropping of the plant, there will be found many small black bodies, sclerotia, varying in size from that of a pin head to a grain of corn, in or upon or under the sick portions of the plant. These, too, are absolutely characistic of sclerotiniose.

These three characters—the dropping, the cotton-like mycelium, and the sclerotia—if carefully observed, enable any one to pronounce with certainty as to whether or not a given bed or plant is affected with sclerotiniose.

History of Sclerotiniose in America.

The disease characterized by the somptoms indicated above is termed *Sclerotiniose,* from the fungus *Sclerotinia,* which is its cause.

Since one of the chief symptoms of sclerotiniose, the symptom which certainly first catches the eye of practical lettuce growers, is a dropping and rotting of the outer leaves, followed usually by dropping and rotting of the rest of the plant, this disease has come to be called "the drop," by lettuce growers in many sections of the country. These symptoms may be produced by several different causes. "The drop" is, therefore, not one single definite disease. It is rather a condition or a symptom, just as lameness of horses is a condition or a symptom, not a disease. Lameness may be due to spavin, which is one disease, or to tuberculosis, which is another, etc. So "the drop" may be due to *Sclerotinia,* to *Pythium,* to *Botrytis,* etc., each of these causing

a separate disease and each requiring different treatment according to the nature of the cause.

The first definite knowledge of the existence of lettuce *sclerotiniose* is contained in a communication by Smith, of Massachusetts, in 1900. The disease was then first clearly and accurately characterized and attributed to its causal fungus, *Sclerotinia libertiana.* While this date is the earliest of accurate knowledge concerning this disease, it was in all probability seriously injurious long before that time, and many lettuce troubles reported from different parts of the United States and attributed to other causes, were doubtless really due to it.

In North Carolina, "the drop," probably in all cases true sclerotiniose, first attracted the attention of lettuce growers around New Bern in 1897, at Fayetteville in 1901, at Warsaw in 1902. It was mentioned by the author of this bulletin in his Annual Report of 1907 to the Director of the Station, and was the subject of a press bulletin during the same year.

Sclerotiniose is now known to occur, as is shown in the accompanying map, in all of the South Atlantic States, North Carolina, South

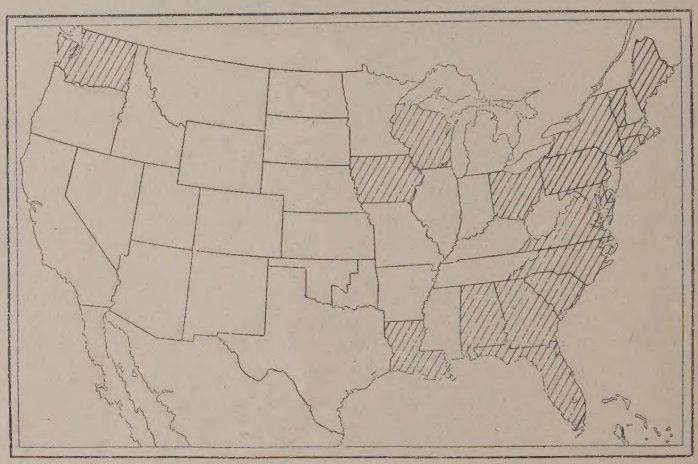


FIG. 4—States shaded are those in which sclerotiniose has been reported. It is not known to exist in others.

Carolina, Alabama, Georgia and Florida, and also in Louisiana, Massachusetts, New York, Ohio, Pennsylvania, Connecticut and Rhode Island, Wisconsin and Iowa, Washington, Vermont, Maine, Maryland, Deleware and Virginia. While not definitely recorded from other States, it probably occurs in many of them, particularly near the Atlantic seaboard.

From what is known of the disease, it is certain that it persists long and multiplies in territory once infected, and rapidly invades new regions. It is, therefore, increasing the area under its tribute yearly,

and will continue to become of wider significance, especially as the lettuce industry broadens.

Summarizing the history of sclerotiniose, it may be said to have attracted attention first about 1890 in Massachusetts; in 1896 in Florida; in 1897 in North Carolina; in 1904 in Wisconsin; and to now possess practically the whole Atlantic seaboard and some of the more Western States.

Amount of Damage.

The extent of the damage varies with the severity of the epidemic and with the value of the crop affected. In 1900, in Massachusetts, Stone and Smith placed the proportion of plants succumbing to the disease at from 15 to 85 or 95 per cent of the crop. They say: "The latter percentages are very exceptional, as growers are not content to experience this loss more than once without making radical changes in their methods. Practically entire crops have been destroyed by drop alone, to our knowledge, and the majority of growers in Massachusetts have experienced at one time or another a loss of from 15 to 40 per cent. The loss of 25 per cent from drop is no uncommon experience in a large number of lettuce houses, and when we consider that these houses each may contain from 6,000 to 12,000 plants, worth from 40 cents to $1 per dozen, some idea of the loss may be obtained."

In Florida the loss is very severe, being sometimes complete.

In South Carolina whole crops are frequently destroyed and the lettuce industry seriously threatened, as is shown in the following quotation from a personal letter: "Several years ago I grew lettuce quite extensively for Northern markets, but had to give it up on account of the damping off. * * * Lettuce is not grown here as extensively as in former years, principally on account of this disease."

In Maryland, sclerotiniose does damage in many greenhouses.

In Alabama, sclerotiniose is reported by Wilcox to do much damage in those places where lettuce is grown on a large scale. In Auburn and Montgomery it is repeatedly met, with great loss.

In New York, some growers, says Stewart, "have had considerable trouble with the drop. It certainly is one of the troublesome diseases of lettuce." Whetzel, of the same State, says: "It (the drop) occurs more or less commonly in all greenhouses about this State and sometimes in lettuce fields."

Damage in North Carolina.

In North Carolina this disease now shows itself to greater or less extent at New Bern, Wilmington, Maxton, Fayetteville, Willard, Raleigh, and probably at numerous localities where lettuce is of less importance. The damage done by it in 1906 is variously estimated at 10 per cent, 20 per cent, 33 per cent, 50 per cent, and 70 per cent, by different growers. At Fayetteville the damage from this disease was estimated at from 10 to 50 per cent of the total value of the crop. Around Wilmington the loss was placed at 10 per cent. At New Bern estimates varied from 33 1-3 per cent to 50 per cent, while at Maxton the loss was placed at 20 per cent.

The disease sometimes appears the first season the crop is grown in a given soil, often not until many crops have been raised. When once it does gain a foothold in a bed it persists, multiplies and increases, until usually the grower is forced to move the bed to new regions, often to very soon meet again a similar fate. Thus the loss to the crop is coupled with the loss attendant upon moving the lettuce bed and frames, irrigation and heating pipes to new land, and the leaving of the enriched soil to go to a newer and poorer one.

Cursory Description of the Causal Fungus.

The cause of sclerotiniose is a fungus belonging to the genus *Sclerotinia,* a genus which is well known on account of its many destructive species, among them being two that are particularly conspicuous, one causing a serious and widespread apple rot and the other causing one of the worst of peach diseases. The fungus is known technically as *Sclerotinia libertiana* Fuckel. It was first described in 1869, and bears its present name, libertiana, in honor of Marie Anne Libert, who published on parasitic fungi from 1813 to 1837. The plant body of this fungus consists of delicate branching, mold-like threads called the mycelium, which may, with the microscope, or, if abundant, with the naked eye, be seen in or on the affected parts of the lettuce plant. No diseased part is free from them, and they are, on the other hand, never present without being accompanied by a condition of disease. It has been definitely proved beyond all doubt that these fungous threads are the actual cause of the disease, and that nothing else can cause this disease.

This fungous mycelium, coming in contact with a lettuce leaf, exudes a poison which kills the nearby cells of the lettuce plant. The cell walls are then dissolved and the mycelium makes its way through or between them. It dissolves also the contents of the cells, and absorbs the resulting nutrient solutions to further its own development. The mycelium thus grows larger, kills more cells, consumes them and continues to advance rapidly through the affected leaf, until the whole leaf is a soft, slimy, rotten mass. The invasion continues into the main stem, then upward to the central bud and "heart" of the head, out into other leaves, downward through the root, until every portion of the plant has been killed and the nutritious parts consumed.

Environmental conditions may, to some extent, change the course of the disease. The fungus grows best in abundant moisture. Sometimes this leads to a more rapid decay of the inner protected portion of the head, and a plant which, to casual inspection, appears healthy may prove upon close examination to be, at heart, a slimy, rotten mass. Again, through one-sided infection the decay may progress much more rapidly upon one side than upon another, resulting in complete death of one side before the other shows any symptom of disease.

As a rule the mycelium is not visible to the naked eye on leaves until the nutriment within the leaves has been nearly or quite exhausted by the fungus. When this time is reached the mycelium begins its external appearance as the loose, cottony growth referred to above. The most profuse development of this aerial mycelium occurs in the region

of more humid atmosphere, such, for example, as on the under side of leaves lying upon the ground, between leaves, or at the base of leaves; in fact, anywhere that the air is so situated as to cause it to remain especially damp.

Soon after the appearance of the aerial mycelium in profuse quantity, it may be noted that in each region where the mycelium is dense there appear one or more centers of aggregation, composed of very densely

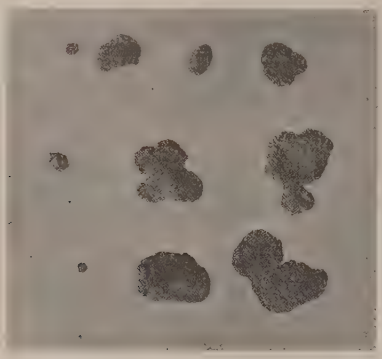


FIG. 5—Sclerotia of various sizes, natural size.

intertangled and interwoven mycelial threads. These denser masses enlarge, increase in density and finally become solid masses of tightly compacted mycelium. The resulting bodies are called *sclerotia.* The

FIG. 6—Germinating sclerotia showing the stalks arising from them and the discs borne on the stalks.

sclerotia are at first colorless, then pale salmon color, and finally black on their exterior and flesh colored within. When first formed they are buried in and covered by mycelium, and are only to be seen by tearing this mycelial covering away. As time passes this mycelium is lost, the remains of the lettuce plant disappear, and the only visible evidence of the plant or the fungus is the sclerotia, many of which are produced in each sick plant.

The sclerotium germinates under suitable conditions, usually after a lapse of several months to nearly a year under field conditions. This it does by sending forth several thread-like sprouts about one-thirty-second of an inch in thickness. These sprouts expand at the end, developing a horn-like or cornucopia-like disk called the *apothecium*. This disk is, in the field, borne just at the surface of the ground with its face directed upward.

Microscopic examination of the disk shows it to consist of two parts: (1) lower basal part, supporting (2) an upper layer which consists of very numerous small, slender tubular bags or sacs (asci) which bear the spores of the fungus.

FIG. 7—Asci in which the spores are borne.

It is seen, then, that the disk is essentially an organ whose function is to produce myriads of spores.

When ripe, these spores are ejected from the sacs by pressure, being forced into the air often to a distance of several feet, where, caught by air currents, they may be carried quickly for great distances. The spores, under suitable surroundings, germinate and send forth small, thread-like sprouts.

The sprout, with suitable nourishing material, grows rapidly into a vigorous mycelium, which is again ready to invade the living lettuce plant, to again cause disease.

This history of the drop fungus may be epitomized by saying that the mycelium grows within the lettuce plant, causing the disease; produces sclerotia when nutriment is exhausted; rests in the sclerotial condition until opportune conditions prevail; the sclerotia then produce disks,

bearing sacs in which are spores; these spores produce a new mycelium which again invades lettuce plants.

The Sclerotia.

Careful count was made of the number of sclerotia upon various parts of affected lettuce plants. The results are given below:

Plant No.	On Ground	In Axils of Leaves	Among Leaves	On Ground in Root	Total
1		9	2	1	12
2		9		2	11
3		9			9
4	1	14	8	10	33
5		9	1	4	14
6		13	2	4	19
7		8	14	4	26
8		23	1		24
9		10		4	14
10		9			9
Total	1	113	28	29	171
Average	1	11.3	2.8	2.9	17.1

These plants from which these records were taken were naturally infected in the lettuce beds. It is seen that the greatest number of sclerotia was formed in the axils of the leaves around the stem. Those formed in the ground on the root were produced only after the root had begun to decay. No plants that were examined, in which the roots had not begun to decay, showed signs of sclerotia below ground, and in very few instances was there any external sign of the fungus in the parts below ground.

If half of a bed of ordinary size, 9 by 200 feet, bearing 2,000 plants, be diseased, it is seen that there may be formed as many as 17,100 sclerotia per bed. It is quite certain that this estimate does not fully represent the actual number formed under conditions of badly infected beds. Estimate has further shown that one sclerotium may on the average produce 10 disks and that each disk can produce about 31,000,000 spores. The number of spores, each potentially an infecting agent, that can come from an infected bed is seen to be something stupendous.

General Relations of the Fungus in Nature.

It is definitely known that the fungus which actually causes this disease, propagates and spreads by means of its spores which are produced from the germinated sclerotia and by its mycelium.

It has been found by long laboratory and field study that the spores are comparatively short-lived even under the conditions most favorable to their longevity. In condition of nature, subject to alternate dryness and atmospheric humidity, they would invariably germinate and in the absence of favorable nutrient pabulum they would die. Thus the spores can not function to any large degree as a means of carrying this fungus over periods of time of any considerable duration.

The mycelium has also been shown to be of comparatively short life and to retain its infecting power but a short time in the absence of nutriment. This, too, can not be regarded as a means of carrying the fungus over long time intervals. Any possibility that the mycelium may remain alive in soil that has borne sclerotinised plants is very remote, probably nonexistent. *The sclerotium is long-lived and well adapted to perpetuate the fungus. It alone of all the structures of the fungus is able to live for sufficiently long periods to bridge over seasons adverse to the growth of the fungus* or long periods of time when no food is available.

The fungus may, therefore, be likened to an annual plant all parts of which, except the seed, die at the approach of winter, the sclerotium in this instance acting the role of the seed.

The sclerotia rest during the period of inactivity of the disease; that is, from the harvest of one lettuce crop until the next crop is present under suitable weather conditions, to permit of infection. They then germinate, and produce disks with a crop of myriads of spores.

Attempts to Control.

Lettuce sclerotiniose some years ago became so bad in greenhouses in Massachusetts that many growers lost practically their whole crop from this cause. Disinfection of the soil, however, proved a practicable remedy under greenhouse conditions.

The two principal methods of soil disinfection early used were (1) by means of chemical solutions, and (2) by means of heat. The first of these has proved to be unsatisfactory and impractical in most cases. The second has been of very great benefit.

One of the earlier methods for heating the soil was to sprinkle it with hot water. This was of some value but not entirely effective, and, moreover, it possessed the disadvantage that it left the bed so wet that it had to remain idle for considerable time in order to become dry enough to work.

The substitution of steam heat as a disinfectant followed, and it is today used with considerable success under greenhouse conditions.

The disinfection of greenhouse soil in one way or another has been used in Rhode Island, Vermont, Ohio, and some other States, nearly always with beneficial results.

In Kentucky, a drop disease is reported to have been checked by subirrigating and placing a mulch of excelsior under the plants to prevent their touching the soil.

Numerous experiments conducted by the writer, mainly on commer-

cial beds at New Bern, with various methods of soil sterilization, including tile drainage and steaming, steaming with a Sargent sterilizer, top-dressing with disinfected soil to various depths, drenching with carbon disulphide, and also with formalin, all failed to show any promise of being satisfactory means of eliminating this disease under our open-bed conditions.

A Treatment That Proved Effective for Open Beds.

The conclusions as recorded above, deduced from several years of laboratory and field study of this disease, especially those conclusions which point to the sclerotia as the only resting stage of the fungus, began to force themselves upon the mind of the writer several years ago.

Those conclusions seemed to be so unavoidable and their logical effect upon horticultural practice so fundamental and so significant that it was deemed imperative to put the question to a crucial test. If the theory as enunciated on page 14 be true, all that is necessary in order to rid a sclerotinia-infected lettuce bed of its pest is to prevent the formation of new sclerotia in it for a period of two or perhaps three years.

To make such a test the first essential was a bed thoroughly and unquestionably infected and so located and managed that it would not be subject to aerial or other extraneous infection.

The experimental lettuce beds of the Experiment Station, located on the farm at West Raleigh, are reasonably well isolated from any other infected beds which might furnish air-borne spores to bring about reinfection. Precaution could easily be taken to prevent access of sclerotia through manure or other sources. The beds are two in number, each 73 feet by 8 feet in size, 30 inches high on the north side, 8 inches on the south side, and are covered in the usual way by canvas, supplemented when need be by burlap mats. They accommodate eight rows of plants, 77 plants to the row, with a total capacity, therefore, of 1,232 plants. The beds were already to some extent infected, owing to the nature of the experimental work that had been conducted in them. This infection was not, however, considered sufficient to make the test crucial.

The first step, therefore, was to thoroughly infect the beds and to demonstrate that they were so infected and to secure a record of the degree of infection. This was accomplished in the spring of 1908 by inoculating several rows, about 67 plants, of the then large, nearly mature marketable lettuce plants with sclerotinia mycelium. Within a few days, April 18, 1908, the plants so inoculated all collapsed and followed the usual course of the disease. These plants, and considerable other lettuce refuse as well, were allowed to remain on the ground, and since the plants were large, the number of sclerotia that remained on the soil was much above the average for sick plants. Thorough infection seemed sure. The lettuce was followed by cucumbers and in October, 1908, the crop was put in in the usual commercial way. The record of disease for that year, presented in Table I and in Fig. 8, shows clearly that a full and thorough infection had been produced.

TABLE I—DAILY RECORDS OF DEATHS FROM SCLEROTINIOSE IN 1908-1909.

Date.	Number of Plants Diseased.
Dec. 3	1
5	2
14	1
20	2
24	2
Jan. 11	21
18	2
20	11
21	2
22	8
23	2
25	5
26	8
27	4
28	3
29	4
Feb. 2	3
4	9
8	10
11	41
13	29
15	12
17	10
20	24
24	73
26	94
Mar. 1	10
5	33
8	6
10	57
12	41
16	25
Total	555

The plants, it will be seen, began to die of sclerotiniose in December, and in January they were dying very rapidly. The last record of disease was on March 16, 1909. A total of 555 plants had died of the disease, or over 45 per cent of those in the beds.

To make records of disease the beds were inspected carefully each day and the cause of disease was determined by culture or microscopic examination, or both, so that no doubt could exist on this point.

The work so far demonstrated the thorough infection of the beds.

The second step of the test consisted in removing the plants before new sclerotia could form, in order to determine whether by so doing the bed could in the course of a few years be freed from infection.

The daily inspection was most rigid. All suspected cases of sclerotiniose were closely watched, and as soon as the symptoms became reasonably indicative of this disease, the plants, entire, were removed to the laboratory. Thus no sclerotia were allowed to mature in the beds. As an additional precaution the locus of the diseased plant was sprayed with a strong Bordeaux mixture.

The lettuce was followed by cucumbers, and in the autumn (October 15, 1909) the next crop of lettuce was set.

It now remained to see whether the disease had increased, as it would have done under the usual modes of handling, or whether a decrease had been brought about by the theoretically hygienic treatment that had been followed.

The record of disease was kept precisely as during the preceding year and the same methods were taken to prevent maturity of sclerotia.

The record is presented in Table II and in Fig. 8.

TABLE II—DAILY RECORDS OF DEATHS FROM SCLEROTINIOSE IN 1909-1910.

Date.		Number of Plants Diseased.
February	18	1
March	4	1
	7	1
	22	1
	28	1
	31	2
Total		7

It will be noted that no plants died of sclerotiniose prior to February 18, and none after March 31, 1910, and that in all only seven plants, or one-half of one per cent of the crop, died.

This very large decrease in disease under one year of hygienic treatment (about 99 per cent of the disease had been removed), was more than was anticipated and indicates even shorter life of the sclerotia and greater loss of sclerotia from rotting than was predicted for them.

The beds were again set with lettuce in December, 1910.

This year approximately the usual number of plants, or, to be exact, 1,113 in all, were set. The crop was raised to maturity, cut, and sold. This year only 9 plants died during the whole season.

Whatever may be thought of the theoretical questions involved, certain practical conclusions stand forth clearly and unmistakably:

1. The lettuce beds were very thoroughly infected (see record of 1908-09, Table I and Fig. 8).

2. Under usual conditions and usual mode of handling, this disease would not have decreased but would surely have increased, or at least remained destructive during following years.

3. Under the treatment that was followed, which had been indicated as the proper one by our laboratory and field studies, the disease decreased to an entirely negligible quantity after one year and remained unimportant through all the next year.

Whether the treatment employed here can be expected always to give such satisfactory results under all conditions of soil and climate, can not, of course, be stated.

The writer feels justified, however, in stating that theoretically this treatment should prove effective and that in the one extremely crucial test to which it has been submitted it has proved thoroughly effective. He feels justified, therefore, in recommending it to lettuce growers who are troubled by this serious disease.

Recommendations.

The following recommendations for the treatment of beds infected with sclerotiniose are made:

1. The bed should be very carefully inspected every other day and every plant that shows indications of this disease should be pulled up and burned.

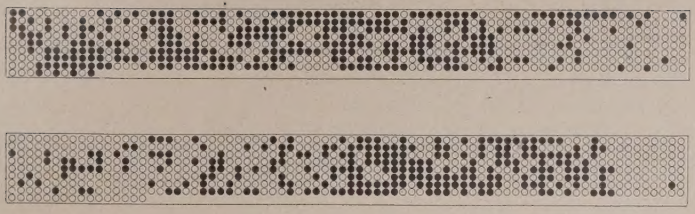
2. The place in the bed from which sick plants are removed should be drenched with Bordeaux mixture or bluestone and water (1 pound to 7 gallons). If these directions are followed, no sclerotia will mature. The number of live sclerotia which will be present in the beds the following year will be very small and the amount of disease will be correspondingly reduced, though it is not to be expected that the disease will be entirely eliminated.

3. The next year the same treatment should be followed with just as much care as was given during the first year. Failure to be careful the second year would be fatal to success.

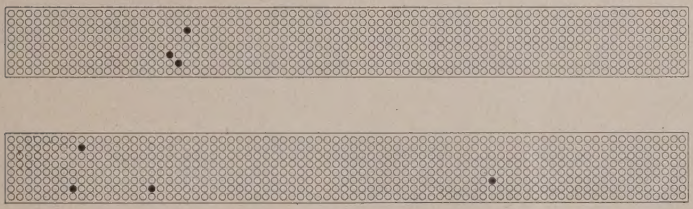
It is probable that two years of this treatment will almost, if not quite, eradicate the disease. During later years, however, the beds should be watched closely and the same procedure followed.

Beds which have been restored to a state of health and beds from which the disease has been partially eradicated should be protected from all sources of extraneous infection. It should be recognized that all refuse that comes from places where this disease exists is liable to bear the sclerotia and convey the disease. Therefore, all refuse from diseased lettuce beds, manure which may contain diseased refuse, must be scrupulously avoided. There is also possibility of aerial infection if infected beds exist nearby. There appears to be no possibility of guarding against such infection, and the method of treatment here advocated can not be expected to give its maximum of results, if infected lettuce beds exist near the beds which are under treatment, since in such cases the danger of reinfection through the air will always be present.

WINTER, 1908-1909.



WINTER, 1909-1910.



WINTER, 1910-1911.

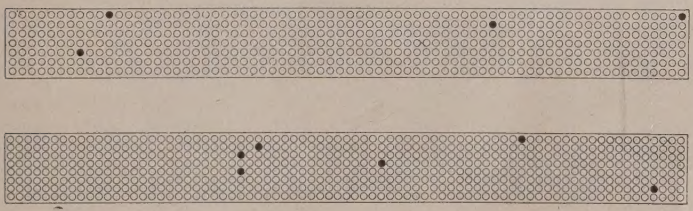


FIGURE 8. Showing plan of Station beds and the exact location of affected plants in the bed during three seasons. • Diseased plant. ○ Healthy plant.